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SUMMARY OF 1989-90 AERONAUTICS DESIGN PROJECTS

N91-18160

AUBURN UNIVERSITY

INTRODUCTION

Four design projects were completed at Auburn University this year under sponsorship of the NASA/USRA Advanced Design Program. These projects are summarized below. Three of the topics were suggested by Mr. Shelby J. Morris, NASA mentor at Langley Research Center, and one was chosen from the AIAA design competition topics. The topics were (1) design of a high-speed civil transport; (2) design of a 79-passenger, high-efficiency, commercial transport; (3) design of a low-cost short-takeoff vertical-landing export fighter; and (4) design of an ozone monitoring vehicle.

HIGH-SPEED CIVIL TRANSPORT

The High Speed Civil Transport (HSCT) shown in Fig. 1 is designed to carry 300 passengers at Mach 3 at an altitude of 70,000 ft and have a range in excess of 6000 n.m. Three major areas of concern were configuration, materials, and propulsion.

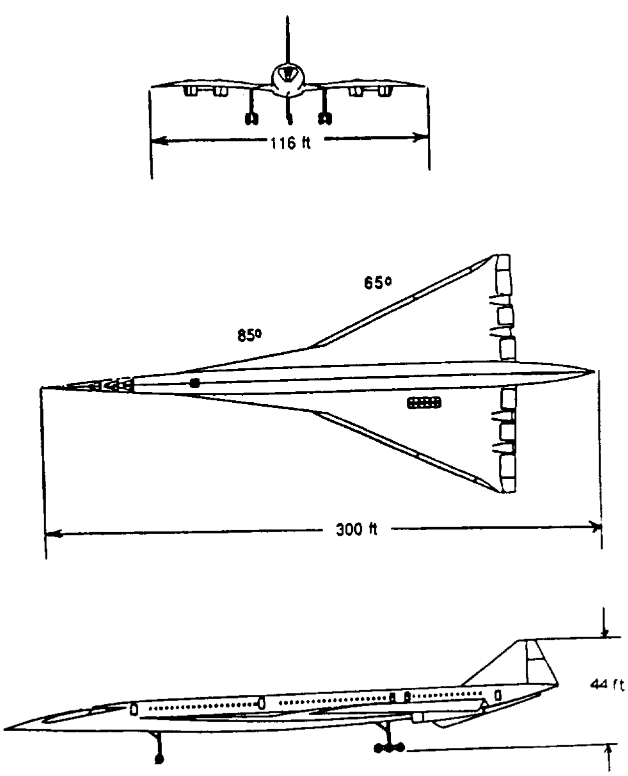

Fig. 1. Basic Configuration of the HSCT

Configuration

The primary goal in configuration design is to minimize drag while maximizing lift. Two wing configurations were considered: a variable-sweep wing and a double-delta planform. The double delta was chosen because of the weight and complexity penalties of the variable-sweep wing. The wing has an area of 9556 sq ft and an aspect ratio of 1.41. Inboard sweep is 85° while the outboard panel is swept 65°. The airfoil is a double wedge airfoil with 5% thickness.

The fuselage is 300 ft long with a diameter of 15 ft. For stability purposes a flight trim fuel tank is located forward of the aircraft center of gravity beneath the passenger compartment.

The HSCT incorporates a vertical tail but no horizontal tail.

Materials

The HSCT will be constructed almost entirely of advanced fiber-reinforced composite materials. Driving forces are the abilities of composites to handle the severe thermal effects induced at Mach 3, and the high strength- and stiffness-to-weight ratios required to keep the weight down. High-temperature areas will use carbon/carbon composites while graphite/epoxy composites will be used wherever possible to reduce cost. Regions susceptible to erosion due to collisions with microscopic materials will be coated with silicon carbide.

Propulsion

Three highly promising engine configurations have been considered: the variable stream control engine (VSCE), the double bypass engine (DBE), and the supersonic through-flow fan engine (STFF). The STFF was chosen because of its lighter weight and better performance over the various flight regimes. The STFF engine concept differs from conventional turbofan designs because the airflow at the fan is supersonic. A schematic of the STFF is shown in Fig. 2. Directly aft of the fan is the engine core inlet. At this point some of the airflow is bypassed while the rest enters the core inlet and is diffused to subsonic speed before reaching the compressor.

Weight savings are seen in the STFF engine in three main areas: the shorter inlet, the simpler single-stage fan, and a lighter, simpler nozzle. The total engine weight savings over the conventional turbofan is estimated at about 31%. A supersonic transport with a gross weight of 760,000 lb is

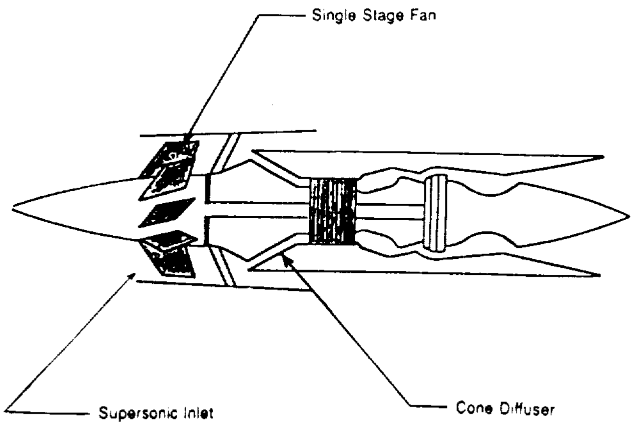

Fig. 2. Schematic of the Supersonic Through-flow Fan

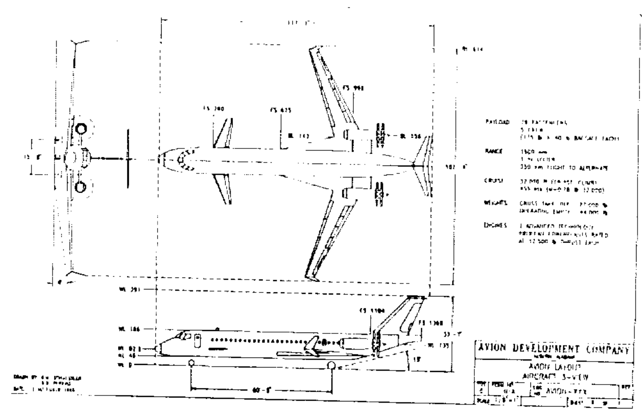

Fig. 3. Avion Configuration 3-View

estimated to have 14% greater range. The propulsion weight reduction provides approximately 5% of the range increase while improved specific fuel consumption provides about 9%.

Conclusion

Development of a HSCT at this time will ensure a stronghold in the aerospace industry for the U.S. well into the next century. At a time when foreign competitors have weakened the U.S. economic position in almost every other area, the aerospace industry continues to be one of the U.S.'s best-performing industries. Market studies have shown that the Pacific Rim nations' economies are the fastest growing in the world. This means inevitable increase in the amount of worldwide travel to this area. If the U.S. aerospace community can develop a baseline HSCT in the near future, it may well boost all areas of our economy.

PRELIMINARY DESIGN OF A 79-PASSENGER, HIGH-EFFICIENCY, COMMERCIAL TRANSPORT AIRCRAFT

INTRODUCTION

The Avion is the next step in commercial passenger transport aviation (see Fig. 3). It aspires to capture for the U.S. the growing world market for a 60-90-passenger, short/medium range transport aircraft. Premier engineering achievements of flight technology are integrated into an aircraft that will challenge the current standards of flight efficiency, reliability, and performance. To achieve higher efficiency the features incorporated in the Avion design are a triwing configuration, propfan powerplants, forward swept wings, winglets, aerodynamic coupling, strakes, T-tail empennage, and an aerodynamic tail cone.

Aircraft Configuration

As an evolutionary hybrid from the conventional and canard configurations, a compromise was reached for the Avion with the three-lifting-surface (or triwing) configuration. This configuration retains the tail of the conventional arrangement, but uses it as an additional lifting surface rather than a stabilizing (down-loading) surface. Among the favorable attributes of the triwing configuration are (1) higher trimmed cruise lift-to-drag ratios; (2) longitudinal primary and trim controls are incorporated in the horizontal tail; and (3) canard is used to trim flap-induced pitching moments.

The Avion uses forward-swept wings that have a significant stall advantage and a favorable effect on compressibility drag. However, they do possess several disadvantages. First there is a substantial weight penalty, which can be overcome by using composite materials. Then there is a stability problem due to the forward location of the aerodynamic center, which must be overcome by careful center-of-gravity location.

The Avion employs a horizontal and vertical tail in a T-tail arrangement. The increased structural weight of this arrangement is offset by sweeping the vertical tail aft to increase the moment arm and thus reduce the size and weight.

Preliminary Weight Estimate

The difficulty of weight estimation was compounded by the unconventional design of the Avion; however, weight estimation was achieved by the iterative fuel fraction method. The results of this method yielded a takeoff weight of 77,000 lb.

A preliminary component weight estimation was made from averaged data from the McDonnell Douglas DC-9-30 and MD-80, and Boeing 727-100 and 737-200 aircraft. The values were then adjusted as deemed necessary by the preliminary weight estimations and structural concerns.

Performance Design Parameter Estimations

The parameters that have a major impact on performance are wing area, takeoff thrust, and maximum lift coefficient. Sizing to meet FAR requirements yielded a wing loading of 100 lb per sq ft at takeoff and a maximum lift coefficient of 2.4.

Propulsion System Integration

Propfans are one of the most promising developments for raising propulsive efficiencies at high subsonic Mach numbers. Demonstrations of this new technology on test aircraft have shown that propfans are clearly superior to current turbofan engines in the area of efficiency while still meeting rigid FAR requirements. Two 12,500-lb thrust engines will be used.

After careful consideration, the decision was made to mount the engines at the rear of the fuselage on pylons. This position alleviates the difficulties of exhaust and slipstream interference while maintaining excellent accessibility of the engines for maintenance and repair.

Propfan propulsion is still an evolving technology. Currently, there are no propfans that meet the thrust and configuration requirements of the Avion; therefore, it is assumed that a power plant will be developed for the Avion.

Conclusions

The Avion has evolved from its initial conception into a promising aircraft design. However, there are several areas that need further attention and were not addressed due to time constraints. Some of these areas are (1) control surface sizing, (2) landing gear sizing, (3) dynamic stability and control analysis, (4) internal structural design, and (5) aircraft systems (e.g., fuel, hydraulic, electrical).

DESIGN OF A LOW-COST SHORT-TAKEOFF VERTICAL-LANDING EXPORT FIGHTER/ATTACK AIRCRAFT

Introduction

In response to the need for a supersonic short takeoff and vertical landing (STOVL) aircraft, AIAA has sponsored a request for proposals (RFP) for a low-cost aircraft meeting these requirements that would be suitable for export and would fill the dual role of a fighter/attack aircraft. These requirements pose several unique design challenges.

Unique Problems of STOVL Design

Since the cost of an aircraft is a function of the amount of new technology that is involved in its development and construction, it is obvious that it will be a major challenge to keep the cost within the range of "low cost." Because of weight minimization needed for vertical flight, lightweight and oftentimes expensive exotic materials will be needed. Also, a new generation of vectored thrust engines will have to be developed since there are no engines on the market that will produce the performance required. One method to contain cost, however, is to use existing avionics packages.

Final Design

After consideration of the many complex design problems concerning STOVL aircraft, and after a considerable amount of research and analysis, a final design for the supersonic STOVL aircraft (the Gremlin) was achieved (see Fig. 4).

The major design features of this aircraft are as follows:

1. Two seats for reduced workload and reduced vulnerability, as well as the ability to be used as a trainer.
2. Improved Pegasus-type, four-poster, low-bypass turbofan engine.
3. Elliptical under-fuselage air intake for efficient airflow at high angles of attack.
4. Highly swept thin wings for low wave drag at supersonic speeds.
5. Folding wings, with folded semispan of 10 ft to reduce storage space.
6. One-piece acrylic bubble canopy for excellent crew visibility.
7. Avoidance of complex curvature to reduce fabrication costs.
8. Incorporation of easy-access panels to simplify maintenance.

Methods of Analysis

Many analyses of the systems comprising the Gremlin were performed during the design period. An initial analysis of most systems was performed using either historical data or rule-of-thumb guesses. The purpose of these initial analyses was to provide a basis for more detailed analyses that followed.

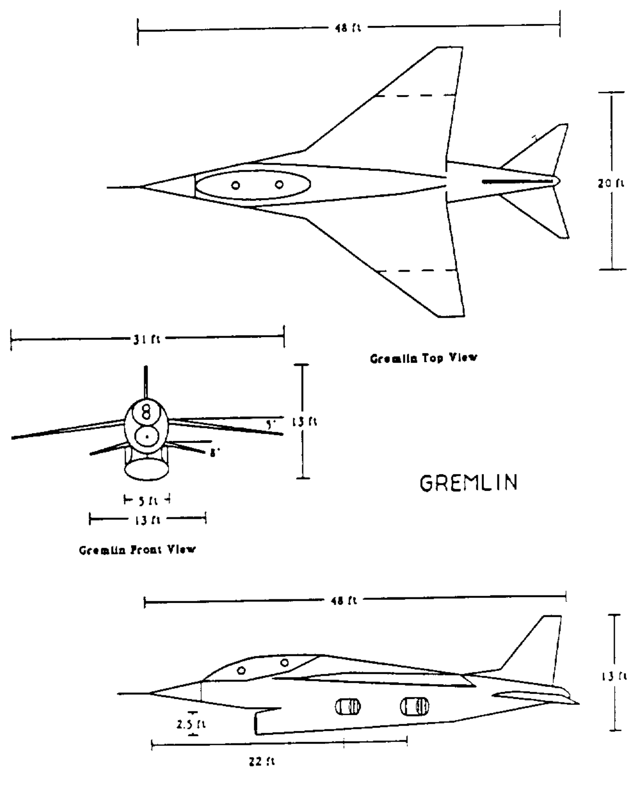

Fig. 4. Gremlin 3-View

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Main Systems

The main systems of the Gremlin supersonic STOVL aircraft are as follows:

Avionics. In order to reduce costs, current production systems will be employed. Since the F-18's dual-role mission is very similar to that desired for the Gremlin, its avionics systems will be used.

Fuel system. The fuel system is located as near as possible to the aircraft's center of gravity. A disadvantage of this situation is the proximity of the fuel tanks to the engine. This vulnerability can be reduced by the use of self-sealing fuel tanks and an inert gas to fill voids to reduce the chance of combustion.

Landing gear. The landing gear system consists of two sets of main fuselage gear designed to absorb most of the stress of impact, and two outboard gears designed to maintain the balance and stability of the aircraft during vertical flight landings.

Weapons. The weapons carried by the Gremlin will be controlled by either the front or rear pilot. Wingtip launching rails can carry the AIM-9L Sidewinder missile, and the hardpoint closest to the fuselage on either wing will carry three Mk-82 500-lb bombs on a multiple ejector rack. Another hardpoint will be located farther out on either wing for additional stores.

Performance Requirements

In order to meet the RFP requirement for cruise at a Mach number of 1.5 for 250 nautical miles, a slightly more powerful Pegasus-type engine is required. This engine will allow vertical takeoff in the air-superiority configuration and requires a takeoff roll of only 200 ft in the ground support configuration, thus beating the RFP requirement of a 300 ft takeoff roll.

Material Selection

The combination of vertical flight and other high-performance requirements suggested the use of exotic materials. However, the RFP also required that the STOVL design be "low cost" to be suitable for export. The Harrier AV-8B uses approximately 30% composites throughout the aircraft structure. Many of the experiences learned in the design process of the Harrier could be applied to the Gremlin. However, the supersonic nature of the Gremlin requires that temperature limitations of composites be taken into account.

Aluminum is still the material of choice when constructing airframes and wing boxes. Its relative low cost and ease of fabrication make it an ideal material for restricting the cost of this aircraft. Titanium, although expensive and complicated to machine, will be used in the high-temperature areas of the aircraft, such as around the engine nozzles.

Overall, the weight of the Gremlin is expected to be around 35% composite materials, 60% traditional aluminum alloys, and the remaining amount various specialized materials such as high-strength steel, titanium, and high-strength plastics.

Cost and Management

The AIAA RFP expected a production run of 500 aircraft. By having a large production run the average cost per aircraft is reduced. These aircraft will be produced over a period of five years. Before production begins, one year will be spent in research analyzing test data. Production then begins at the start of the second year by manufacturing two Gremlins each of the first four months. The first four aircraft will be for flight tests. Evaluation of the test flights will begin the third month of production. After testing is completed, full-scale manufacturing of 10 Gremlins per month will occur for production months 9 through 54. As the production schedule nears completion, the rate of production will decrease to allow for personnel to transfer to new programs.

The average cost per Gremlin aircraft for a production run of 500 aircraft was calculated to be \$18.2 million (1990 dollars).

Conclusions and Recommendations

This design group has concluded that the low-cost Gremlin supersonic STOVL fighter/attack aircraft is a viable design. It is expected that the engine technology required for this design will be available by the projected delivery date of 2005. Although the aerodynamic evaluation is not complete, the preliminary analysis predicts very promising performance.

The potential market for such an aircraft is growing. The large number of Harriers and Hornets sold to other countries is an indication of this trend.

HIGH-ALTITUDE OZONE RESEARCH BALLOON

Introduction

The ozone layer shields the Earth from harmful solar radiation that can cause skin cancer, destroy acids in DNA molecules, and have harmful effects on world climate and vegetation. Research has indicated that a seasonal depletion of ozone concentration exists over Antarctica. Can we conclude that this depletion is a natural occurrence, or are we witnessing a decline in ozone concentration that will appear later in other regions of the world?

Because 97% of the ozone molecules are located in the stratosphere, analysis methods are extremely expensive, time consuming, and inadequate. Moreover, atmospheric scientists are concerned with the possible further destruction of the ozone concentration due to the chemical contaminants released from ozone monitoring vehicles. These concerns have caused a renewed emphasis in the development of high-altitude ozone research balloons. However, limited flight duration and lack of vertical and lateral control have severely limited the widespread acceptance of high-altitude research balloons as the primary method for ozone observation and analysis.

Current Limitations

Ozone research requires a vehicle capable of delivering and supporting a scientific payload at an altitude above 25 km. Also, ozone research analysts emphasize the need for variable altitude profile sampling in order to obtain a representative model of ozone concentration. In addition, a long flight duration is desired in order to reduce production costs and increase the amount of data collected per flight.

Presently used high-altitude ozone research balloons are very limited in flight duration. They maintain their altitude by venting helium and dropping ballast. Thus, the length of the mission is limited by the amount of reserve helium and ballast that is initially carried on the support structure of the balloon.

During the day, the balloon is heated by solar radiation impinging on the surface of the balloon film. As the temperature of the film increases, the temperature of the helium within the balloon increases due to natural convection. As a consequence, the helium expands and the balloon rises. When the balloon ascends to an altitude above the desired sampling range, the balloon is remotely vented and helium is released. As the mass of helium is reduced the balloon descends. When the balloon descends below the minimum range of interest, the researchers can either release ballast or perform a controlled addition of reserve helium.

This cycle of venting and ballasting continues throughout the mission. After depletion of ballast and reserve helium, the mission must be terminated. Currently, average flight times for these types of zero-pressure balloons are three to seven days.

HAORB Design Improvements

In order to lengthen flight duration, the conventional method of vertical control must be improved. The High Altitude Ozone Research Balloon (HAORB) is designed to provide this improvement. It will ascend at a slower rate than its conventional counterpart. Consequently, the venting and ballasting process will occur less frequently and the mission duration will be dramatically increased.

The focus of the HAORB design is the control of heat transfer to the balloon film. The polyethylene balloon film is continually heated during the day by direct and indirect solar radiation along with the reflected radiation from the Earth. As the temperature of the balloon film increases, the helium temperature and its volume subsequently increase. This results in a net upward acceleration of the HAORB that is equivalent to its conventional counterpart. The vertical speed of the HAORB will be controlled by removing the heat that is transferred to the balloon film. By limiting the increase in balloon film temperature, less heat is transferred to the helium. Thus, vertical control is achieved by the use of a cooling system on the HAORB.

Cooling System Operation

The cooling system uses cooling ducts and rotary circulation fans to maintain a balance between the temperature of the atmosphere and the temperature of the helium (see Fig. 5).

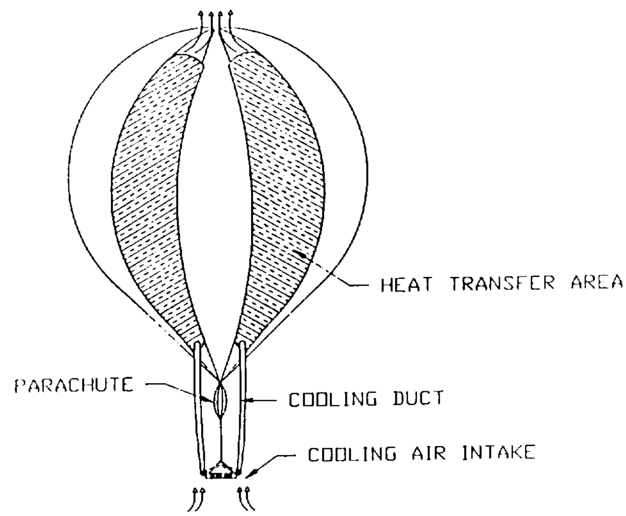

Fig. 5. Configuration of the HAORB at High Altitude

The cooling system cools both the film and the helium. Four cooling ducts are formed by sealing additional panels on the outer surface of the balloon. The four cooling ducts cover approximately one-fourth of the surface area of the balloon, therefore reducing the amount of film surface in contact with the helium that is exposed to solar radiation. The forced circulation of cooler atmospheric air provided by the rotary circulation fans removes heat that would be transferred to the helium from the outer film.

The cooling system receives input from an accelerometer. This information is then used to determine the vertical velocity of the HAORB. As the temperature of the helium increases, the HAORB begins to accelerate upward. When the upward velocity exceeds 0.27 m/sec, the fans are energized. The fans cause forced convection heat transfer from the film to the air. This cools the helium and reduces the acceleration. When the velocity falls below 0.2 m/sec, the fans are secured.

Results

A FORTRAN program was written to facilitate the stepwise integration of the equations describing the vertical motion of both the HAORB and a conventional balloon. The initial conditions assume that the initial velocity and acceleration are zero, the initial film temperature is 5° above atmospheric, and altitude is 26 km. For the test profile conducted from 26 km to 34 km, the HAORB with additional weight of fans, batteries, and solar cells had a substantially longer (about 9 times) mission duration than the conventional balloon with the same reserve helium and ballast.